Extending the Temperature Range of Electronics for Spacecraft

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Abstract

"Very little of the Solar System (or the Universe) is at room temperature."

Many of the interesting places in the Solar System involve extreme environments; these include extreme temperatures, low and high. The traditional means of sending spacecraft into extreme-temperatures environments has been to provide room temperature for the spacecraft electronics using thermal insulation and possibly heating or cooling systems. However, because this approach has serious drawbacks, it is useful to consider an alternative, namely developing electronics that can operate at the same temperature as the extreme environment.

Operating electronics in extreme-temperature environments is not a new idea or a new technique. Electronic devices and systems have been operated down to within a few degrees of absolute zero (–273ºC) and up to +300ºC and higher. There are many examples, for both low and high temperatures, from about 50 years ago using vacuum electron devices, to later times using semiconductor devices. Moderately complex systems based on semiconductor devices are not uncommon.

Often an extreme temperature is not the only factor or stress acting on a spacecraft. There is always the universal factor of *time*, and there can also be radiation, pressure, vibration, shock, or corrosive ambients. The interaction between temperature and these other factors can be complicated. Moreover, electronic components are intricate and can exhibit many mechanisms for change, both within a single material and between different materials. Consequently, it is risky to try to predict aging and reliability based on simple models and assumptions.

High temperatures (high thermal energy) can have undesirable effects such as decomposition, electromigration, interdiffusion, and so on, but low temperatures (low thermal energy) can also have undesirable effects such as "freeze-out" or charge trapping.

In summary, developing extreme-temperature electronics for spacecraft presents a number of technical challenges; however, it can have important benefits in the areas of size, mass, power consumption, efficiency, maneuverability, reliability, and mission success.

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